



BIM – A Revolutionary Technology in Recent Trends of AEC

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Abstract— An infrastructure project consist of a multifaceted set of relationships, between peoples with different professional backgrounds working together to accomplish a very intricate goal. The Architecture, Engineering, and Construction (AEC) industry is still at the very infancy stage with the adoption of Building Information Modeling (BIM) to improve the design, construction, and facility management of construction projects. Therefore, several issues about data acquisition and management arise during the design creation and development of a construction project due to the complexity, ambiguity, and fragmented nature of the construction industry. By transforming the quality of information used in building industry, BIM aims to change construction practice completely. This study helps explore different benefits, additional platform (softwares) and the current trends of why it should be adopted to achieve greater heights even with the most complex structures.

Index Terms - Benefits, Building Information Modelling (BIM), Current Trends, Multifaceted, Softwares.

I. INTRODUCTION

Traditional building design was largely reliant upon two-dimensional technical drawings (plans, elevations, sections, etc.). Building information modelling(BIM) extends this beyond 3D, augmenting the three primary spatial dimensions (width, height and depth) with time as the fourth dimension (4D) and cost as the fifth (5D).^[1] BIM therefore covers more than just geometry. It is a new innovative approach which has changed the way industry professionals worldwide think about how technology can be applied to building design, construction, and management. BIM allows to fully and truly construct a building virtually, and in detail.

II. THE BIM CONCEPT

A. Definition

“Building Information Modeling (BIM) is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conceptual stages, through design and

construction, through its operational life and eventual demolition.”^[2]

It covers geometry, space, light, geographic information, quantities and properties of building components.^[3]

During the BIM-design phase the materials not only can be selected and placed to model the finished structure including concrete slabs, rebar, steel structure, wall and ceiling components, plumbing and electrical fittings but also can be tested for all such parts of conflicts (clash detection) to ensure everything completed together perfectly.

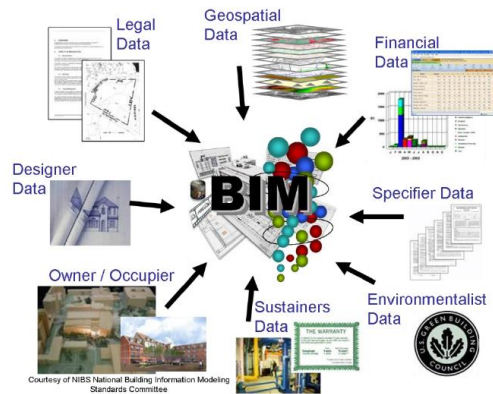


Fig. 1 Various types of information included to form (courtesy, NIBS)

Having the ability to keep information up-to-date and accessible in an integrated digital environment, gives architects, engineers, builders, and owners a clear overall vision of all their projects, as well as the ability to make informed decisions faster.^[3]

Just as a spreadsheet is a tool for thinking numbers ,software built on parametric building modeling technology is a tool for thinking about buildings. And just as a change made anywhere in spreadsheet is expected to update everywhere with no further intervention from the user so as a change made anywhere in parametric building modeler is immediately reflected everywhere.

III. NATURE OF BUILDING INFORMATION MODELLING

The complications of the varied array of information contained in BIM can be daunting, so it becomes necessary to understand the basic nature of these concepts in order to plan and manage their organization well.

A. Virtual Models

Virtual building implies that it is possible to practice construction, to experiment, and to make adjustments in the project before it is actualized. Virtual mistakes generally do not have serious consequences, provided that they are identified and addressed early enough that they can be avoided “in the field”.

Virtual models generally fall into two distinct classes: surface models and solid models. Models that are only for visualization purposes may be made with surface modelers concerning the size, shape, location, etc., and well suited for aesthetic design, planning, and marketing purposes. Virtual construction techniques primarily employ solid modelers are often referred to as smart models because they allow the simulation of much more than merely the visual aspects of a building project. A solid model has the additional advantage of having the possibility to generate 2D views that can be developed into conventional construction documentation. In theory a BIM should be able to communicate all project information so that no 2D drawings will be necessary; but in reality the software tools and permitting processes will have to develop further, before the need for 2D drawings can be eliminated.

B. Parametric Modelling

Parametric object modeling provides a powerful way to create and edit geometry. Typically, parametric rules create relationships between different elements of the design. So for example, a rule might be created to ensure that walls must start at floor level and reach the underside of the ceiling. Then if the floor to ceiling height is changed, the walls will automatically adjust to suit. If a colour scheme for a building is changed, every object that has that colour attribute will also change. Other parameters might include; positional data, dimensions, manufacturer's data, algorithms describing form and so on. It allows the different alternatives shown to be generated in close to real time.

The Beijing National Stadium constructed for the 2008 Summer Olympics used specialist parametric modelling software to develop a bowl geometry optimized for athletics that would also work well for football after the Olympics. Similarly, the geometry of Shanghai Tower, was developed parametrically using the Grasshopper

modelling tool, enabling the relationship between form and wind loads to be determined.^[4]

C. Model Intelligence

Model intelligence refers to the fact that information may be contained in a 3D virtual model. Parametric information refers to the information that distinguishes one particular component from another one that is similar. This may refer to a wall, all walls have wall qualities in common, but each actual wall, although made with the same “wall tool,” may have different parametrics; its dimensions, or material makeup (wood or metal studs, type of sheetrock, etc.), or supplier information, etc., may vary. Each aspect of this type of information can be programmed into the specific wall object so that it accurately represents what the project requires. Such modeling with parametric components is called object-based modeling.

D. Links

1) Model to information link

Parametric object information is information that is part of a specific object in the project model. The nature of the link is automatic; it is easy to edit the model object to reflect whatever changes are required in the information.

2) Model to model link

It means that for a model to be able to be compatible with models created by other software tools, it is necessary for all of them to be translatable into a uniform file format, so that all the object's information can be transferred correctly. The International Alliance for Interoperability (IAI) has created a uniform platform, and there is a large effort going into the development of standards to define interoperability between models.

E. Project Information

Successful project management relies on access to information and its proper management. One of the chief advantages of a BIM is the fact that all the information related to a project can now be contained in, or linked to, the BIM. It is a challenge, however, to manage this complex array of information containers well.

IV. BENEFITS OF BIM

A. Improved Information Flow

Because a digital model represents a unified description of a building, the digital model can be accessed by the architects, MEP engineers, contractors, facilities managers, and owners at different phases in the building life cycle to add, extract, or modify information in support of their role.

B. Better Design Visualization

Many persons have difficulty in understanding 2D drawings, however a 3D model, clearly represents the project and allows the visualization of many of its features, even with surprisingly few details. Whether placing an air handler in a mechanical room, or routing piping or ductwork, the ability to virtually build the HVAC system and visually examine it in 3D can provide added assurance that all components will fit when construction begins.

C. Improved Cost Estimating

BIM can simplify and help provide better cost estimates, can also increase the speed and accuracy of estimates, providing a better gauge of the impact of design changes.

D. Improved Energy Analysis

Here again, BIM can simplify and improve the accuracy of energy analysis because the data required to perform such analysis is resident in the digital building model.

E. Reduced construction costs

Clash detection can be used long before construction begins to show where parts of the design occupy the same space. This can reduce or eliminate the need for changes in the field during construction. It also helps prefabricate building components, such as duct or pipe runs saving assembly and installation cost. The period which is spent on the design can be cut by about half at half the cost. Moreover, "half time at half cost" will not just save the money, it is also reducing the time to the market.^[5]

F. Building History

It serves as an important information library. For example, if a building component fails, the building information model can be used to identify its location, manufacturer, model number, performance specifications, and other pertinent data to most efficiently repair or replace that component.

If a portion of the building is being remodeled, the building information model can be used to identify concealed components, such as piping, ductwork, and electrical equipment to promote informed decisions on the remodel design.^[6]



Fig. 2 Building Information Modelling using Autodesk

V. AN INDIAN PERSPECTIVE

BIM is next generation construction technology that is changing the face of design in the construction industry worldwide. Though relatively new to India, it is picking up rapidly and gaining popularity amongst architects and developers. Engineers and architects are also utilizing this tool to push the design envelope and explore newer concepts and techniques in structural services and MEP requirements, as project stakeholders increasingly use BIM for improved coordination through its design and virtual building capabilities.

In India BIM is also known as VDC: virtual design and construction (VDC). India is an emerging market with an expanding construction market and huge potential for large scale residential and commercial development (because of population and economical growth). It has many qualified, trained and experienced BIM professionals who are implementing this technology in Indian construction projects and also assisting teams in the USA, Australia, UK, Middle East, Singapore and North Africa to design and deliver construction projects using BIM. In spite of this, and India's vibrant building sector, BIM usage was reported by only 22% of respondents to a 2014 survey.^[7]

VI. BIM PLATFORMS

Although BIM is relatively new, it is also a trend that is penetrating the Construction industry fast and I would even dare to say, with no way back.

BIM software can be divided in the following groups:^[3]

- Architecture
- Sustainability
- Structures
- MEP
- Construction
- Property Management

Major architectural, engineering, and construction (AEC) software providers, such as Autodesk, Bentley, Gehry Technologies and Graphisoft, provide the core software necessary to create a digital building model.^[6]

The different marketing strategies lead to packages with different collections of functionality. In this review, the major BIM platforms are considered generically, from the perspective of its primary product, with references to other products running on the same platform.

A. Autodesk Revit

Revit is the best-known and current market leader for BIM in architectural design. It was introduced by Autodesk in 2002. Autodesk Revit Architecture is a robust architectural design and documentation software

application created by Autodesk for architects and building professionals.



Fig. 3 Project made on Autodesk Revit

The tools and features that make up Revit Architecture are specifically designed to support building information modeling (BIM) workflows. By utilizing BIM as opposed to computer-aided drafting (CAD), Revit Architecture is able to leverage dynamic information in intelligent models allowing complex building structures to be accurately designed and documented in a short amount of time.^[8]

It runs on both 32- and 64-bit processors and versions of the OS. As a tool, Revit provides an easy-to-use interface. Revit has a very large set of product libraries, particularly its own Autodesk SEEK library for specification and design objects. It carries information for about 850 different companies, and about 13,750 different product lines (including over 750 light fixtures).

Revit Architecture 2010 is used to develop the 3D model. Built for Building Information Modeling (BIM), the software helps to capture and analyze most innovative design concepts and maintain vision through documentation. It also generates every schedule, drawing sheet, 2D view, and 3D view from a single foundational database, automatically coordinating changes as the project develops and evolves.^[9]

B. Bentley systems

Bentley is the global leader dedicated to providing architects, engineers, geospatial professionals, constructors and owner-operators with comprehensive software solutions for sustaining infrastructure. Founded in 1984, Bentley has more than 3,000 colleagues in 50 countries, more than \$600 million in annual revenues.^[10] The Bentley System is based upon Microsoft station technology. It is a more robust program than Revit and extensively used by Army Corps. of Engineers.^[11]

Bentley has a large array of additional systems, many of which acquired in support of its civil engineering products. These include:

Table I. Bentley Additional Systems

RAM Structural	GEOPAK Civil Engineering Suite
RAM Steel	Bentley Building Electrical Systems VSi for AutoCAD
RAM Frame	Facility Information Management
RAM Connection	ConstructSim
RAM Foundation	Bentley Building Mechanical Systems
RAM Concrete	Bentley Tas Simulator
RAM Elements	Hevacomp Dynamic Simulation
RAM Concept	Hevacomp Mechanical Designer
Pro Concrete	Bentley PowerCivil

In 2015, Bentley announced ProjectWise CONNECT Edition joins MicroStation and Navigator CONNECT Editions in general access, and has also introduced ContextCapture, which allows users to produce high-resolution 3D models of existing conditions using photos taken with any digital camera.^[12]

C. ArchiCAD

ArchiCAD is an Architectural BIM CAD software for Macintosh and Windows developed by the Hungarian company Graphisoft. With "Virtual Building" concept, ArchiCAD came to be regarded as the first implementation of BIM^{[13][14]}. It has also been recognized as the first CAD product on a personal computer able to create both 2D and 3D geometry, as well as the first commercial BIM products^{[13][15][16]} and considered "revolutionary" for the ability to store large amounts of information within the 3D model.^[17]

ArchiCAD translates AutoCAD into new plans; merges and refers it into existing plans ArchiCAD. It also controls the import and export processes of AutoCAD plans.^[18]

The current version of ArchiCAD is Release 14.0. As a platform, ArchiCAD has links to multiple tools in different domains. These are denoted (GDL) and (IFC), respectively: Structural: Tekla (If), Revit Structure (If), Scia Engineer (Dir) SAP & ETABS (IFC), Fem-Design (IFC), AxisVM (IFC) ArchiCAD version 14 has an intuitive interface and is relatively simple to use.

D. Tekla structures

Tekla Structures is offered by Tekla Corp., a Finnish company founded in 1966 with offices worldwide. Tekla has multiple divisions: Building and Construction, Infrastructure, and Energy. Tekla Structures is a building information modeling software able to model structures that incorporate different kinds of building materials, including steel and concrete. Tekla Structures was formerly known as Xsteel (X as in X Window System, the foundation of the Unix GUI).^{[19] [20] [21] [22] [23] [24]} Modeling scopes within Tekla Structures includes

Structural Steel, Cast-in-Place (CIP), Concrete, Reinforcing Bar, Miscellaneous Steel and Light Gauge Drywall Framing.^[21]

As a platform, Tekla offers interface support for a wide range of other applications. (Refer Table II)

Table II. Application programming interface.

Application	Company	Capabilities
SAP2000	Computers & Structures, Inc	Structural analysis
STAAD	Bentley	Struct. design & analysis
STRUDS	SoftTech	Struct. design & analysis

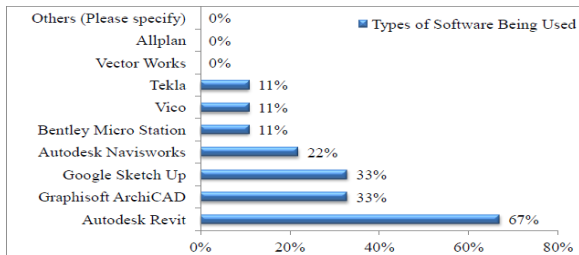


Fig. 4 Usage of Different Softwares^[25]

Table III. The efficiency difference between CAD and BIM application for particular project at different phases^[26]

Task	CAD (hours)	BIM (hours)	Hours saved	Time savings
Schematic	190	90	100	53%
Design development	436	220	216	50%
Construction documents	1,023	815	208	20%
Checking & coordination	175	16	159	91%
Total	1,824	1,141	683	

E. Latest Advancements in BIM.^[27]

1) Project Tango:

Google’s Project Tango is a unique system for handsets and tablets to leverage BIM data, easily capture and analyze 3D models and spatial data recorded by device-mounted cameras that can be edited on the device.

2) BIM in the Cloud Computing:

While 2013 raised the public’s awareness of big data and cloud computing, it was 2014 that saw this technology begin to come into its own as a BIM tool. Now this technology is helping AEC professionals all over the world collaborate together in way never before possible.

This collaboration is accelerating designs while reducing errors and costs.

VII. SURVEY & DATA ANALYSIS

A. G2 Crowd Publishes Winter 2015 Rankings of the Best Building Design and BIM Software. According to it, to qualify as a Leader, a product must receive a high customer satisfaction score and have substantial market presence. Revit and AutoCAD were named Leaders. High Performers have high customer satisfaction scores with a smaller market presence than Leaders. ArchiCAD, Vectorworks Architect and DataCAD were named High Performers. DataCAD earned the highest overall customer satisfaction score in the report. Across all building design software and BIM software, reviewers reported the product they use meets their requirements at an average rate of 86%.^[28]

B. Top BIM Firms:^[29]

Table V. 2011 BIM Revenue of Top Firms

Rank	Company	2011 BIM Revenue (\$)
Architecture		
1	HOK	398,217,301
2	HDR Architecture	327,690,000
3	Perkins+Will	274,336,000
Engineering		
1	Jacobs	355,021,036
2	URS Corp.	275,000,000
3	Stantec	181,300,000
Construction		
1	Turner Corporation	5,458,100,812
2	URS Corp.	4,150,000,000
3	Hensel Phelps Cont.	2,230,890,000



Fig. 5. Hearst Tower



Fig. 6. Liberty Mutual Headquarters

VIII. SUCCESSFUL IMPLEMENTATIONS OF BIM.

- 1) University of Washington, Husky Stadium Renovation, Seattle, WA.
- 2) Northern Kentucky University, Bank of Kentucky Center, Northern Kentucky, KY.

- 3) Liberty Mutual Headquarters, Boston, MA.
- 4) Hearst Tower, New York, NY.
- 5) Great American Tower, Cincinnati, OH.
- 6) NASCAR Hall of Fame, Charlotte, NC.
- 7) National Intrepid Center of Excellence at Bethesda Naval Hospital, Bethesda, MD
- 8) Middle Tennessee Medical Center Replacement Hospital, Murfreesboro, TN.
- 9) Miami Children's Hospital Emergency Department Expansion, Miami, FL
- 10) Cleveland Clinic, Egil and Pauline Braathen Neurology Institute and Cancer Center, Weston, FL
- 11) Yale University - Arts and Architecture Addition & Renovations, New Haven, CT
- 12) The Reva and David Logan Center, Chicago, IL. ^[30]

Table IV. Worldwide awareness & usage of BIM^[31]

COUNTRY	BIM USAGE	BIM AWARENESS (USAGE OR NOT USAGE)	BIM NO AWARENESS
UNITED KINGDOM	33%	60%	7%
GERMANY	13%	56%	31%
FRANCE	7%	18%	75%
SPAIN	13%	16%	71%

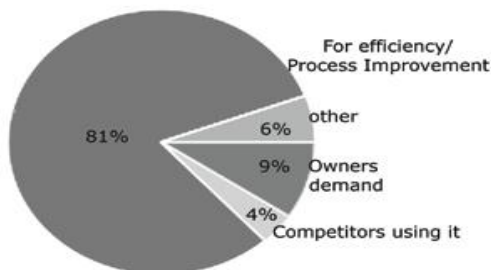


Fig. 7(a). Causes for starting BIM.

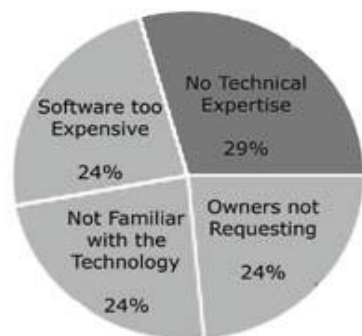


Fig.7(b). Reasons for not using BIM.

Table V. BIM Application in a Construction Project.

Phase	Stage	Uses of BIM
Pre-construction	Planning	Identifies schedule sequencing or phasing issues
	Design	Facilities better communication and faster design decision Perform clash detection and clash analysis Increases design effectiveness
	Scheduling	Enables project manager and contractor see construction work sequences, equipment, materials and track progress against logistics and timeless establishment
	Estimates	Enables generation of takeoffs, costs and measurements directly from a 3-Dimensional(3D) project model
Construction	Site analysis	Decreases costs of utility demand and demolition.
	Construction	Enables demonstration of construction process, including access and exit roads, traffic flows, site material and machineries Provide better tracking of cost control and cash flow Enables tracking of working real time, faster flow of resources and better site management
Post-construction	Operation/ Facilities management	Keep track of built as set Manages facilities proactively Enables scheduled maintenance and provides review of maintenance history

IX. CONCLUSION

Building Information Modeling (BIM) can be considered an important transition in design practice. Unlike CAD, which primarily automates aspects of traditional drawing production, BIM is a prototype change. By partially automating the detailing of construction-level building models, BIM redistributes the allocation of effort, placing more emphasis on conceptual design. Complete construction using BIM is the future, there is no way out of it. The survey explores the BIM potentials when used in the field to better communicate and integrate construction information across different trades, allowing efficient work processes and better decisions. More specifically, the study concentrates on the latest trends in BIM

showcasing the different structures built using it.

The major reasons for fewer BIM users in India being high cost of software, no government involvement, low demand from the clients and lack of skilled or trained employees the rampant myths about BIM usage. This study aims at creating awareness and removal of all such myths by presenting enough of the benefits BIM provides. Thus, BIM allows to stretch innovative thinking and break grounds in the application of this technology.

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